TVA

Tennessee Valley Authority, Post Office Box 2000, Soddy-Daisy, Tennessee 37379

J. L. Wilson
Vice President, Sequoyah Nuclear Plant

September 28, 1992

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555

Gentlemen:

In the Matter of	)	Docket Nos. 50-327
Tennessee Valley Authority	)	50-328

SEQUOYAH NUCLEAR PLANT (SQN) - ADDITIONAL HYDROGEN RULE (10 CFR 50.44) ANALYSES (TAC R00356 AND R00357)

References: 1. TVA letter to NRC dated January 29, 1988, "Additional Hydrogen Rule Analyses Submittal"
2. TVA letter to NRC dated February 19, 1987, "Additional Hydrogen Rule Analyses Submittal"

By Reference 2, TVA committed to obtain and review reports submitted by Duke Power Company to NRC on additional hydrogen analyses that were being performed and determine their applicability to SQN. By Reference 1, TVA indicated that the commitment dates of Reference 2 could not be met because of the unavailability of the Duke submittals, restated the necessity for these reports to complete TVA's commitments, and that the commitment due dates would follow the Duke effort. The Duke effort for Catawba Nuclear Plant was described in detail in Attachment 1 of a letter from Duke to NRC dated April 25, 1986, which is contained in Enclosure 1 to this submittal. Duke completed this effort and provided the results to TVA on March 10, 1992. However, this report has not been submitted to NRC on the Catawba docket.

Reference 2 committed TVA to perform evaluations on applicability of this Duke effort for the hydrogen rule to SQN and to perform an analysis on issues not addressed by this effort. TVA has completed these evaluations, and the results are provided in Enclosure 2. The four degraded core sequences selected by Duke for the Catawba analysis are acceptable as the dominant sequences for hydrogen generation. The individual plant evaluation (IPE) for SQN also identifies these same sequences as the dominant sequences for hydrogen generation during degraded core accidents. The SQN IPE was performed in accordance with Generic Letter 88-20 and submitted to NRC by letter dated September 1, 1992.

TVA considers the analytical assumptions and parameters associated with the Catawba Station to be applicable to SQN for equipment survivability after a degraded core accident and confirms acceptance of the Catawba analysis for applicability to SQN.

The results of the Catawba analysis, in combination with the original SQN specific analyses, meet the requirements of the hydrogen rule (10 CFR 50.44), and TVA considers all associated commitments to be complete based on this submittal.

Please direct questions concerning this issue to K. C. Weller at (615) 843-7527.

Sincerely,

J. L. Wilson

J. L. Wilson

Enclosures
cc (Enclosures):

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ENCLOSURE 1

DUKE POWER COMPANY
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April 25, 1986

Mr. Harold R. Denton, Director
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U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Mr. B. J. Youngblood, Project Director
PWR Project Directorate No. 4

Re: Catawba Nuclear Station
Docket Nos. 50-413 and 50-414
McGuire Nuclear Station
Docket Nos. 50-369 and 50-370

Dear Sir:

On April 8, 1986, representatives from Duke Power Company and the NRC Staff met at the NRC's offices in Bethesda, Maryland to discuss hydrogen control measures at Catawba and McGuire. As a followup to that meeting, Duke has prepared a plan for resolution of concerns on equipment survivability (Attachment 1) and on fans and doors (Attachment 2). A schedule for resolution of these outstanding issues is also included in the respective attachments.

Very truly yours,

Hal B. Tucker

ROS:slb

Attachments

xc: Dr. J. Nelson Grace, Regional Administrator
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Mr. W. T. Orders
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ATTACHMENT 1

PLAN FOR RESOLUTION OF CONCERNS ON EQUIPMENT SURVIVABILITY

Purpose and Summary Description

The purpose of this document is to describe a proposed plan for the resolution of the issue of equipment survivability during deliberate ignition of hydrogen in the containment at Catawba. The plan consists of three parts as follows:

1. Evaluation of the hydrogen and steam releases to containment for an appropriate selection of accident sequences which lead to large releases of hydrogen into containment. The selection of accident sequences and the method of analysis is described below.

2. Using the results of the first part of the plan as input, evaluation of the response of the containment and its associated systems to the accident sequences, and a determination of the pressure and temperature in containment as a function of time. The specific method of performing this analysis, and the major assumptions and parameters to be used, are described below.

3. Using the results from the first two parts of the plan, determination of the response of equipment in containment to hydrogen burning and evaluation of its survivability. The steps in this part of the plan include selection of the equipment to be analyzed, determining the appropriate models for the analysis, comparison of results from the analysis with equipment qualification test data and hydrogen burn survivability tests performed under the sponsorship of NRC and EPRI, and assessing the margin associated with the equipment response.

Detailed discussion of each part of the plan follows.

Analysis of Accident Sequences

The first step in this part of the plan is the selection of the specific accident sequences to be analyzed. A spectrum of accidents sequences that envelope the range of hydrogen and steam release rates will be studied. Since steam flow through the core is the limiting factor for cladding oxidation, primary system pressure is the parameter of importance dua to its effect on steam availability. Therefore the following sequences will be analyzed:

S1D (low primary system pressure)

S2D (intermediate primary system pressure)
TMLU (high primary system pressure)

As a result of NRC staff concerns about sequences involving ECCS failure in the recirculation mode, S2H will also be investigated. These accident sequences envelope the possible primary system pressure conditions under which hydrogen could be developed in the primary system, the release rates of that hydrogen to containment, and conditions in containment at the time of hydrogen release. Each sequence of events will be terminated by resumption of ECCS prior to excessive core melting, consistent with previous analyses of degraded core hydrogen generation.

Analysis of these accident sequences will be performed using MAAP 2.0. This code was developed by IDCOR and its contractors in order to assess the progress of degraded core events. The specific assumptions to be used are to be based on the best estimate models in MAAP which meet with NRC staff approval as a result of their ongoing review. In addition, the total amount of hydrogen to be considered for each sequence will be that produced by 75% m/w reaction of the clad or the maximum amount which can be generated by adjusting the time of resumption of ECCS flow, without employing non-mechanistic assumptions or extrapolations in order to force the release rate to be equivalent to 75% m/w. The S2D accident sequence will be extrapolated to 75% m/w, if necessary, in order to meet the requirement of the hydrogen rule that the effectiveness of the system be shown for hydrogen releases up to 75% of the clad oxidized.

The output of the MAAP analysis will be time histories of the mass and energy releases for hydrogen and steam into the containment. These time histories will be compared to those reported in References 1 and 2 to ensure that they are representative of calculations performed using MARCH.

Analysis of Containment Response to Hydrogen Burning

Several possibilities have been considered for performing the containment analysis portion of the plan. The long run times associated with CLASIX would make analysis using CLASIX very expensive. In our containment code development work, we have modified CONTEMPT4-MOD5 by adding better models for the ice condenser ice bed and doors, but deficiencies in the hydrogen burn models would require more development. For these reasons it has been determined that the HECTR code would represent the best choice for containment analysis. Action has been taken to obtain HECTR from the National Energy Software Center. Following receipt and installation of HECTR, it will be examined to ensure that the ice condenser model is not excessively conservative. Our concern over the ice bed model is prompted by the work reported in Reference 1 wherein ice bed meltout appears to occur

prematurely when compared with LOTIC and CLASIX results. Any changes we make in HECTR as a result of our review will be documented. If HECTR cannot be made operational on our computer system, either CLASIX or CONTEMPT4-MOD5 will be selected for the analyses.

Regardless of which containment analysis code we select, a number of parameters will have to be determined for input to the code. These parameters affect the results of the code significantly and therefore need to be agreed to prior to starting the work. The following are the proposed containment analysis assumptions and parameters:

1. Spray and fan operation - based on best estimate analysis methods, it will be assumed that both trains of sprays and fans are started automatically at the proper time and operate throughout the accident. The fan performance will be based on vendor supplied curves derived from test data. Spray performance will be based on FSAR values for injection and recirculation sources. As a sensitvity analysis, response of the containment will be calculated for the case of a single train of fans and sprays available.

2. Ignition and propagation criteria - following study of the various hydrogen combustion tests performed by NRC and EPRI contractors, the following ignition and propagation criteria have been selected for a base case analysis.

a. Lower compartment - ignition and propagation at 6% hydrogen by volume.

b. Ice condenser - no igniters are present in the bed or lower plenum, therefore ignition cannot occur. Propagation upward from the lower compartment at 6%, propagation downward from the upper plenum at 8%. In the upper plenum, ignition at 8% hydrogen by volume, propagation downward from the upper compartment at 8% hydrogen. The upper plenum ignition and propagation concentrations will be adjusted downward in those cases where substantial ice melting (greater than 80%) has occurred and little or no ice remains in the ice bed.

c. Upper compartment - ignition at 6% hydrogen, propagation from the upper plenum at 6% hydrogen.

d. Deadended compartments - ignition at 6% hydrogen, propagation from the lower compartment at 6% hydrogen.

In all compartments, burning is suppressed if the steam concentration is greater than 55% by volume or if the oxygen concentration is less than 5% by volume.

3. Combustion completeness - combustion will be 60% complete at 6% hydrogen or less, 100% complete at 8% hydrogen.

4. Flame speed - a better measure of this parameter would be burnout time, the time it takes for hydrogen burning to burn completely in a compartment. The following burnout times will be used for the containment compartments:

lower compartment - 10 seconds
lower plenum and ice bed - 8 seconds
upper plenum - 7 seconds (will be increased consistent with the previous discussion on ignition concentration for accident sequences with less than 20% ice in ice bed)
upper compartment - 10 seconds
deadended compartments - 10 seconds

5. Heat transfer coefficients for containment heat sinks and equipment in containment - as reported in Reference 3, with a possible modification to the ice heat transfer coefficient to reflect proprietary correlations used in LOTIC and CLASIX.

6. Ice condenser drain temperature - 150F, as used in early CLASIX analysis, based on Westinghouse test data, for the early part of the transient when ice melt rate is significant. This temperature will be adjusted downward in the cases where the ice melt rate is very low at the time of the hydrogen burning.

7. Compartmentalization - as given in the example reported in Reference 3.

The results of the containment analyses will be time histories of compartment temperatures and indication of the number of hydrogen burns occurring in each compartment.

Justification for the selection of hydrogen burning parameters for the base case:

The selected hydrogen burn parameters are based on study of the various hydrogen burning experiments carried out under the sponsorship of NRC, the ice condenser owners, and EPRI. These are the test series at Factory Mutual, Acurex, Sandia (VGES), and Nevada Test Station (NTS). It is recognized that none of these experiments duplicates containment conditions during an accident exactly and that some judgment must be applied in order to establish parameters for analysis based on these experiments. iHowever, it is the best data available and its use in this regard is consistent with the best estimate nature of the analysis to be performed.

Lower Compartment Parameters The relevant data is obtained from experiments in which fan induced turbulence is present. The sources of turbulence in the lower compartment will be the flow of the air return fans coming from variour openings between the lower containment and the dead ended compartments and the continuing release of steam and gasses from the primary system.

It is noted from experiment that ignition occurs consistently at less than 6% hydrogen by volume under these conditions. Of particular interest are tests P-3, P-6', and P-7 from the NTS series in which hydrogen at 6% concentration or less was ignited in the presence of steam quantities representative of those found in the lower compartment during hydrogen release. These tests also indicate flame speeds in the range of 3-4 feet/second which translates based on compartment geometry to a burn time in the lower containment of 10 seconds. The actual burnout time in the lower containment will be longer than this due to the congested arrangement of equipment and the downward propagation of the flames.

Upper Plenum - the various experiments show that dry mixtures, as would be expected at the outlet of the ice condenser ice bed would be ignited at 5-6% hydrogen. The use of 6% in the analysis reflects the uncertainty over the presence of a fog in the flow out of the ice bed. Analysis performed by Westinghouse for McGuire (Reference 6) and tests 3.3 and 3.4 from Acurex confirm that mixtures of 8% hydrogen will ignite in the presence of fog. Flame speed is based on NTS tests P-4, P-5, and P-13' wherein upward propagation goes at 4-6 feet/second. This gives a compartment burnout time of 7 seconds based on igniter spacing and compartment geometry. This is considered conservative because the NTS tests were for upward propagation and propagation in the ice condenser is predominately downward and horizontal.

Upper compartment - the upper compartment parameters are based on the results of NTS experiments P-7 and P-22 in which mixtures of less than 5.5% hydrogen were easily ignitable and burned quickly in the presence of fans and spray. The burn time was conservatively extrapolated from test P-22 to be 10 seconds, though this is considered to be much faster than an actual burn would take in the upper compartment due to the larger volume over the NTS vessel (a factor greater than 30) and the predominate downward propagation. Ten seconds is also consistent with the spray droplet fall time which has traditionally been used for upper compartment analysis.

Dead Ended Compartments - conditions in the dead ended compartments are much like those of the lower compartment, with fan induced turbulence due to the air return fans, but at lower concentrations of steam in the atmosphere. Ignition concentration is selected at 6% hydrogen, but the flame speed and burnout times are longer due to the decreased turbulence (no blowdown sources in dead ended compartments) and the larger volume to igniter ratio (igniters are not as closely spaced). These assumptions are expected to be of no consequence to the analysis because previous experience shows that hydrogen does not burn in the dead ended compartments.

Where the analysis appears to be particularly sensitive to the selection of parameters, and where there is justification from experiment of theory that alternative parameters are possible,

sensitivity studies will be performed. Guidance for such sensitivity studies will be based on that given in References 1 and 3. Of interest is the case of continuous hydrogen burning in the lower compartment because of results seen in certain of the NTS dynamic injection tests. The conditions under which such continuous burning might occur in containment will be evaluated by comparison to the parameters used in the NTS tests. If it appears appropriate for the ice condenser containment conditions, continuous burning will be considered in the evaluation of equipment survivability in lower containment.

Certain additional models not previously employed in the CLASIX analysis reported in Reference 4 will also be used this time. Work by Westinghouse has confirmed the ability of the ice condenser drain flow to act as a lower compartment spray, desuperheating the atmosphere and condensing steam. Because of the consequences of the condensation of steam (increasing the hydrogen concentration) of lowering the temperature (less severe environments for lower compartment equipment survivability), this model will be included in the containment analysis done for hydrogen burning if NRC staff approval for that model has been obtained. In addition, in order to minimize the differential pressure developed between the upper and lower compartments if upper compartment burning is shown by analysis to occur, the containment analysis will include specific models for the bypass paths between upper and lower containment. These paths include the refueling canal drains and the ice condenser door bypass areas, including the ice condenser drains.

Establishment of Equipment Survivability

The first step in the process of establishing equipment survivability is to determine the specific equipment required to survive hydrogen burn events. The basic requirement is that equipment to maintain the unit in safe shutdown, to monitor the progress of the event, and to maintain containment integrity must be operable following hydrogen burning. This selection process has been performed for Catawba and the results reported in Reference 4. We plan to continue using this list.

There are two possible approaches to determine equipment survivability analytically. The first approach is to model the equipment of interest in the containment analysis code as heat sinks and determine the temperature response of the equipment directly. Due to the unsophisticated nature of the heat sink models in HECTR (one dimension slabs only), it would be necessary to modify the code to include the proper models. This approach will be investigated during the performance of the work contained in this plan and will be used if it proves to be feasible. Our analysis would be similar to that tried by Sandia and reported in

Reference 5, but with the elimination of excess conservatism and inappropriate assumptions.

An alternative approach to the analysis of the equipment temperature response is to repeat the method used in Reference 4 in which the equipment is modeled as a series of coupled differential equations based on conductive, convective, and radiative heat transfer relationships. These equations are solved using a general purpose differential equation solver. This approach will be used if the direct method described above proves infeasible.

Following the determination of the temperature response of the equipment, a comparison will be made with the equipment qualification temperature in a manner similar to that reported in Reference 4. In addition, the results of the extensive amount of actual testing of equipment performed under EPRI and NRC sponsorship will be reviewed to determine its applicability and cited wherever it is relevant.

Conclusion

Following completion of all analyses to be performed, appropriate revisions to Reference 4 will be prepared and submitted to NRC. It is expected that sections 4, 5, and 6 of Reference 4 will be substantially rewritten as a result of this work. The work will include parameters specific to both McGuire and Catawba and will be applicable to both stations.

Schedule

The work required to carry out the plan is extensive. There are uncertainties in the proposal, such as the use of HECTR, which make determination of exact durations difficult. The following schedule is proposed:

September, 1986 - complete MAAP analysis of accident sequences. Complete installation and checkout of HECTR, or identify and make operational the alternative method of containment analysis. Submit the results of the MAAP analysis to NRC for approval.

December, 1986 - following staff approval of the MAAP analysis, begin containment response calculations.

March, 1987 - complete containment response analysis, submit results to NRC for approval.

June, 1987 - following NRC approval of the containment response analysis, begin equipment survivability analysis.

September, 1987 - complete equipment survivability analysis and submit to NRC for approval.

December 31, 1987 - following resolution of all comments, prepare and submit appropriate revisions to Reference 4.

This schedule is consistent with the nature of the analysis (being associated with beyond design basis events) and the conflicting responsibilities of the principal analysts involved in performing the work.

References

1. Camp, A. L., et. al., "MARCH-HECTR Analysis of Selected Accidents in an Ice Condenser Containment," NUREG/CR-3912, December, 1984

2. NRC letter (D. L. Wiggenton) dated December 16, 1985, reporting on a meeting held December 5, 1985 between NRC and IMEC

3. Camp, A. L., et. al., "HECTR Version 1.0 User's Manual," NUREG/CR-3913, February, 1985

4. Duke Power Company, "An Analysis of Hydrogen Control Measures at McGuire Nuclear Station," October, 1981, complete through Revision 14, April, 1986

5. Dandini, V. J., and W. H. McCollough, "HECTR Analysis of Equipment Temperature Responses to Selected Hydrogen Burns in an Ice Condenser Containment," NUREG/CR-3954, February, 1985

6. Tsai, S. S., "Fog Inerting Analysis for PWR Ice Condenser Plants," Westinghouse Electric Corporation, October, 1982